4.15 Geologic Hazards and Soils

4.15.1 Introduction

The land surfaces upon which vegetation grows typically reflect from thousands to millions of years of complex geomorphic processes, including uplifting, faulting, weathering, deposition, mass wasting, and erosion. The following sections describe types of hazards and characteristics of soils potentially affected by treatments implemented under the proposed program.

4.15.2 Geology

As a result of tectonic and volcanic activity the geology of California is quite complex and gives rise to a great diversity of landforms. The state can be divided into 11 geomorphic provinces, which refer to areas that have a similar landscape, representing different types of rocks (Table 4.15.1). Most Bioregions for the state cross one or more of the geologic provinces.

4.15.3 Landslide Hazards

Landslides consist of the downslope movement of soil and rock under the influence of gravity. The geologic and topographic features of the landscape are the primary determinants of the shear strength of the hillslope materials (i.e., resistance to landslides) and hillslope shear stress (i.e., propensity for landsliding). Landslides occur when the shear stress exceeds the shear strength of the materials forming the slope (Gray and Leiser, 1982). Climate and vegetative cover also affect landslide hazard because of their influence on soil root support and moisture.

Factors contributing to high shear stress on hillslopes include:

- steep slope
- high mass loading (e.g., through high soil moisture levels or placement of fill material)
- slope undercutting (e.g., through erosion or excavation)
- soils that vary in volume (shrink and swell) in relation to moisture content

Factors contributing to low shear strength of hillslope materials include:

- bedding planes that dip in the same direction as the slope at the same or a lesser degree of steepness
- high water pressure in soil pores (e.g., saturated soil underlain by a restrictive layer)
- presence of faults or joints
- weak materials (e.g., soft soils or rock, unconsolidated materials, fine grain size) (Gray and Leiser, 1982)

The leading indicator of high landslide potential is evidence of previous landsliding (Gray and Leiser, 1982). Features indicating the presence of landslides or high landslide potential are described in Table 4.15.8.

Table 4.15.1
Geologic Provinces of California (modified from CGS, 2002)

Geologic Provinces	Bioregions	Description of Geologic Provinces
Colorado Desert	Colorado Desert	A low lying desert basin; 245 feet below sea level at its lowest point. Characterized by silt deposits of extinct Lake Cahuilla.
Cascade Range/Modoc Plateau	Modoc	Characterized by young volcanic rocks. Mount Lassen represents the southern extent of the Cascade Range that extends north through Oregon and Washington. The Modoc Plateau consists of lava flows, tuff beds and small volcanic cones.
Sierra Nevada	Sierra Nevada	The Sierra is a granitic batholith nearly 400 miles long. The massive granites of the Sierra extend up to 14,500 feet in elevation at the top of Mt. Whitney and deposit sediments into the Great Valley.
Great Valley	Sacramento Valley, San Joaquin Valley	A narrow valley extending 400 miles long and about 50 miles wide. Sediment deposits are immense with accumulation of sediment from hydraulic mining. Most of the valley resides at sea level.
Klamath Mountains	Klamath/North Coast	The province is considered to be a northern extension of the Sierra, but has more complex geology. The Trinity Alps, Marble Mountains, Salmon Mountains and Siskiyou Mountains are the major ranges.
Transverse Ranges	Central Coast, South Coast	A series of steep mountain ranges and valleys that trend east-west. Comprised of Cenozoic sedimentary rocks that have folded and faulted due to compression forces of the San Andreas fault.
Basin and Range	Mojave	Located on the eastside of the Sierra they represent the westernmost limit of a province that extends east to the Wasatch Range in Utah.
Peninsular Ranges	South Coast	The ranges in this province include the San Jacinto, the Santa Ana, Santa Rosa, and Laguna mountains. Represents the northern extent of a range that extends south into Baja. The geology is similar to the Sierra with granitic rock intruding the older metamorphic rocks.
Coast Ranges	Klamath/North Coast, Central Coast, Bay Area/Delta	A series of northwest trending mountain ranges that parallel and are influenced by the San Andreas fault. The Coast Ranges are composed of thick Mesozoic and Cenozoic sedimentary strata.
Mojave Desert	Mojave	The Mojave is a broad interior region of isolated mountain ranges separated by expanses of desert plains. It has interior enclosed drainage and many playas. Bounded by the Garlock fault to the NW and the San Andreas fault to the SW.

Landslides can be classified as active or dormant, based on how recently they have moved. Active landslides typically display cracks or sharp, bare scarps. Vegetation is usually more sparse on active landslides than on adjacent stable ground; if trees are present, they are usually “jackstrawed” (i.e., leaning), indicating that ground movement has occurred since they became established. Dormant landslide features have typically been modified by weathering, erosion, and vegetative growth and succession.

Active landslides are generally more unstable than dormant landslides and may require mitigation measures to avoid mobilization. Excavation, the use of heavy equipment, soil saturation, or the removal of root support can mobilize active landslides. Although dormant landslides are less likely to be mobilized by human activities, portions of dormant landslides (e.g., their steep headwalls and margins) are often unstable.

Several types of landslides and associated landforms can be associated with vegetation management in California and are described below. These landforms have distinct hazard indicators and require special management practices to reduce the hazard.

Translational and Rotational Landslides

Translational and rotational landslides are moderate or slow, relatively deep-seated movements of typically cohesive rock masses. These movements commonly occur along bedrock bedding planes that dip parallel to the surface, as may be observed at rock outcroppings. Translational slides consist of downward displacements of material parallel to the ground surface; they commonly occur along bedding planes, faults, and contacts between bedrock and overlying deposits. Rotational slides (or “slumps”) occur along a well-defined curved surface and are likely to occur in incompetent, clayey bedrock material under saturated soil conditions. Most translational and rotational slides feature a nearly vertical scarp near their head or sides. Slide deposits are typically hummocky. The presence of sag ponds or wet-site vegetation may indicate the impaired drainage that is characteristic of slide deposits.

Earth Flows

Earth flows consist of the slow movement of saturated soil and debris, often following a slump. They are composed of clay-rich materials that swell when wet, thus reducing intergrannular friction and shear strength. They usually occur in areas where low soil permeability restricts groundwater movement. They often feature hummocky, highly erodible surfaces.

Debris Slides

Debris slides refer to the movement of unconsolidated material along a shallow, flat failure plane. They usually occur on slopes exceeding 65% where shallow bedrock forms an impervious layer that concentrates water near the surface. Debris slides often occur during intense storms in response to excessive pore water pressure within the saturated surface layer. As with other landslides, the presence of bedding planes aligned parallel to the slope is an indicator of high debris slide hazard.

Debris Flows

Debris flows are often initiated by the discharge of material into a stream channel from debris slides on adjacent hillslopes or by failure of fill materials at stream crossings caused by high flows.

Debris flows most commonly occur in the South Coast bioregion, but can also occur in the Central and North Coast bioregions. In southern California, debris flows frequently follow wildland fires in response to even small storms (Wells, 1987). High debris-flow hazards are characterized by steep channel gradient, unstable adjacent hillslopes, and unstable sediment stored in stream channels. The USGS has developed detailed maps for most of Southern California that identify areas that are prone to debris flows when triggered by intense rainfall events (USGS Open File Report 03-17; http://geopubs.wr.usgs.gov/open-file/of03-17/).

Inner Gorges

Inner gorges are oversteepened stream banks extending from the stream channel to the first break in the slope above the channel. The slope generally exceeds 65% and is formed by debris sliding and erosion caused primarily by the downcutting of the stream channel and undercutting of landslide toes by stream erosion (California Department of Conservation, 1997).

Debris Slide Amphitheaters/Slopes

Debris slide amphitheaters and slopes are characterized by steep slopes that have been sculpted by many debris slides. Although areas within these landforms are typically well-vegetated, they usually also feature debris slide scars, incised depressions, areas of active debris sliding, and exposed bedrock.

4.15.4 California Paleontology

Time is divided by geologists into eras (Precambrian to Cenozoic) and periods (Cambrian to Quaternary). There is a further division into epochs, such as the Pleistocene epoch of the early Quaternary period. The Quaternary period, including the present, is the most recent, and Holocene (late Quaternary) are used here. These units are quite uneven in elapsed time, the older intervals generally being of much longer duration. Rocks in the California are as old as the Precambrian era (Figure 14.15.1). Rocks may contain fossilized remains of marine and terrestrial life of ages past. The following information on paleontology in California is presented from the Paleontology Portal website from the University of California Museum of Paleontology (http://www.paleoportal.org/index.php?globalnav=time_space&sectionnav=state&name= California).

Cenozoic

Quaternary - Most Quaternary sediments are gravels laid down by large river systems throughout the state. Both of these types of deposits contain well-preserved vertebrate and plant fossils, similar to the flora and fauna we see today. Glaciers developed in the Sierra Nevada during colder climate intervals, and large lakes formed in the Great Valley, Owens Valley, and the Salton Sea. The floras from lower elevations indicate a more moderate, Mediterranean climate that was warmer to the south. Marine terrace deposits can be found along the coast, mainly in Southern California.

Tertiary - Because much of western California was underwater during the Tertiary, marine deposits occur throughout the state. Marine sandstones and shales were alternately deposited and then eroded as sea levels changed. These marine rocks contain a diverse fauna of corals, bivalves, gastropods, scaphopods (tusk shells), echinoderms, and foraminifera (single-celled protists with shells). Although deposits from river channels, floodplains, and deltas can be found in northern counties, terrestrial sediments are more common in the south. The floras of these deposits indicate that the climate became less tropical and more temperate throughout most of the Tertiary. Increased tectonic activity in the Late Tertiary uplifted the Coast and Transverse Ranges, eliminated the inland sea that had filled the Central Valley, and generated widespread volcanism. California's grasslands were filled with herbivores and carnivores.

Mesozoic

Cretaceous - Subduction of the Farallon Plate continued beneath the western margin of the North American Plate. The ancestral Sierra Nevada rose and was eroded, and the Coast Ranges began to rise. The eroded sediments from the ancestral Sierra Nevada (sand, gravel, and volcanic material) were deposited east of the rising Coast Ranges. These sediments became the rock layers of the Central Valley (i.e., the Great Valley Sequence) and record the position of the Cretaceous shoreline in California. Exposed throughout the Central Valley, the marine rocks have yielded abundant fossil remains of ammonites, marine reptiles, bivalves, and even plants.

Jurassic - Beginning in the Jurassic, subduction of the Farallon Plate under the western edge of the North American Plate generated widespread volcanism, began creating the ancestral Sierra Nevada, and added exotic terranes composed of oceanic sediments and crust to the continent. Ammonites, marine reptiles, bivalves, and echinoderms were common in coastal waters and their fossils are now found in the Jurassic shales, sandstones, and limestones of Stanislaus, San Joaquin, and San Luis Obispo Counties. Terrestrial sediments contain a record of gymnosperms (seed-bearing plants) such as ginkgoes, cycads, and conifers from a warm, moderately wet climate. This map indicates additional exposures in the northern part of the state.

Triassic - The western edge of North America during the Triassic would have been somewhere around the California-Nevada border. Although still in the tropics, the climate of western North America was becoming more arid as rising mountains blocked moisture-bearing winds coming from the seas. Shales, sandstones, conglomerates, dolostones, and limestones were deposited in the shallow-to-deep marine environments off the coast. Exposures in Northern California (Shasta and Plumas Counties) have yielded a diverse marine fauna, including fossils of ammonites, brachiopods, bivalves, echinoderms, and marine reptiles.

Paleozoic

Permian - Permian rocks in California represent both shallow and deep marine environments inhabited by brachiopods, echinoderms, corals, molluscs, and cartilaginous fish. The shales, sandstone, conglomerates, dolostones, and limestones deposited in these environments are found in Northern California in Shasta and Butte Counties.

Carboniferous - Most of California was under water during the Carboniferous, and the warm coastal waters were inhabited by algae, bryozoans, crinoids, molluscs, corals, and cartilaginous fish. On land, the swamps and estuarine environments were home to horsetails, ferns, and large seed-bearing plants (gymnosperms) like seed ferns (extinct gymnosperms) and club mosses (lycophytes), as well as very large insects. Carboniferous rocks containing marine fossils are not shown on this map, but can be found to the north in Shasta County and to the south in Inyo County. All of these rocks were most likely exotic terranes that rafted in from the west by tectonic activity, and accreted onto the continent.

Devonian - During the Devonian, most of what is now California was still under water. Scattered exposures of Devonian shale, sandstone, limestone, and dolostone can be found in the Northern Sierra Nevada, as well as to the south in the White Mountains, Inyo Mountains, and places around Death Valley. Exposures of Devonian-age rocks are not common in California, and the few fossils collected have been mainly invertebrates: brachiopods, corals, stromatoporoids (sponge-like animals with calcareous skeletons), ammonites, crinoids.

Silurian - During the Silurian, the western edge of North America was still underwater. Tabulate corals and stromatoporoids (sponge-like animals with calcareous skeletons) dominated the reef communities that were built up in shallow, warm waters on banks and shoals. These warm waters were also teeming with brachiopods, cephalopods, gastropods, bivalves, and crinoids. Although not shown on this map, Silurian sandstones, shales, conglomerates, cherts, dolostones, and some altered sedimentary rocks can be found in the Northern Sierra Nevada, White Mountains, Inyo Range, and places near Death Valley.

Ordovician - Along the northwestern edge of the ancient continent of Laurentia (which is now the western edge of North America), a broad carbonate platform continued to develop. Warm waters of this shallow limy sea were home to a great diversity of animals including graptolites, trilobites, brachiopods, colonial corals, bryozoans, and stromatoporoids (sponge-like animals with calcareous skeletons). Although not shown on this map, Ordovician sandstones, shales, conglomerates, cherts, dolostones, and some altered sedimentary rocks in California are found mainly in the White Mountains, Inyo Mountains, and in places around Death Valley.

Cambrian - Limited exposures of Cambrian rocks can be found in the White Mountains, Inyo Mountains, and in a few places around Death Valley. These limestones, dolostones, and shales were deposited in the warm waters as a broad, shallow carbonate platform. Archaeocyaths, trilobites, inarticulate brachiopods, early echinoderms, and sponges dominated these shallow warm waters.

Precambrian

Precambrian - Precambrian rocks in California include igneous and metamorphic basement rocks, as well as some sedimentary rocks (limestone, dolostone, and sandstones, which have often been altered to quartzite). These sedimentary rocks can be found in the White Mountains, Inyo Mountains, and around Death Valley. Most of these rocks do not contain fossils, although some traces and a few fossils have been found in the younger geologic formations of Precambrian age.

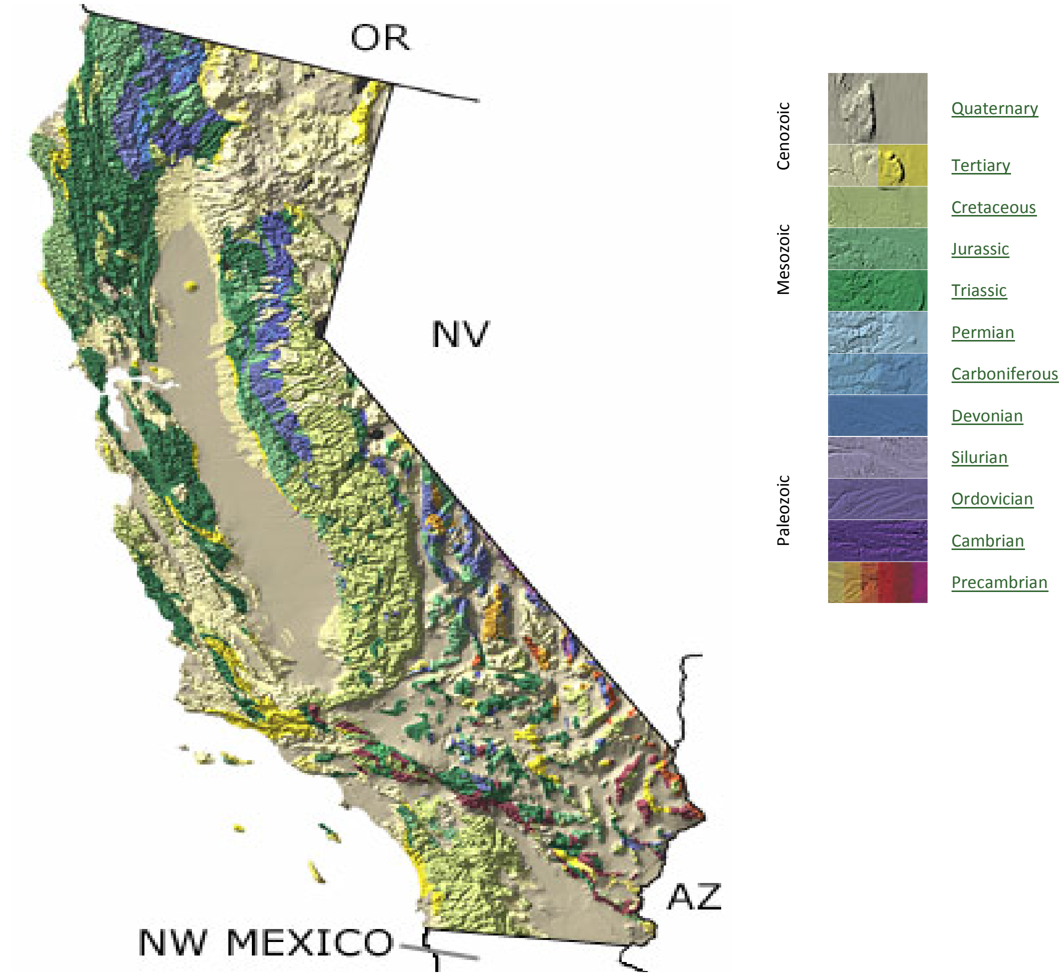

Figure 4.15.1 Geologic time periods across California (PaleoPortal, 2006; www.paleoportal.org)

4.15.5 Soils

Soil is the primary medium for plant growth and storage and movement of water and nutrients in ecosystems. Soil formation is controlled by the interactions of parent material, topography, climate, biota, and time. These factors create the physical and chemical characteristics that distinguish various soil types. Soils are composed of air, water, and inorganic and organic matter. Inorganic materials are primarily minerals that may or may not provide nutrients to plants. Organic matter includes living and dead plant and animal material. Varying depths of litter and duff protect soils. Litter consists of identifiable plant material, including needles, leaves, and woody debris of different sizes; duff consists of decomposing organic detritus that will become part of the soil organic matter.

Soils in the VTP area vary from deep, poorly drained, clayey soils on level terrain to shallow, droughty, gravelly soils on steep slopes. They also vary widely in their susceptibility to erosion, compaction, and formation of hydrophobic substances during fires, as described below.

Although the level of detail varies, most of the state's soils have been mapped to some level of detail by the Natural Resources Conservation Service or the Forest Service. Mapping is generally most detailed in the parts of the state used for cropland; rangelands, forest lands, and desert regions are often mapped at a low level of detail or have not been mapped. Table 4.15.2 provides a summary of the dominant soil orders found in each Bioregion. Alfisols, Mollisols, Inceptisols, and Ultisols are commonly associated with forest land. A brief description of the soil properties for each soil order is provided at the end of this section (pages 4.15-16 and 4.15-17).

Table 4.15.2
Summary of the Percentage of Dominant Soils Order by Bioregion (STATSGO)

Bioregion	A	C	D	E	H	I	M	U	V
Bay Area/Delta	21	0	0	18	3	7	38	1	13
Central Coast	18	0	2	25	0	6	44	0	4
Colorado Desert	0	0	28	72	0	0	0	0	0
Klamath/North Coast	25	3	1	10	0	47	9	3	2
Modoc	15	3	5	12	0	14	47	0	5
Mojave	2	0	29	68	0	1	1	0	0
Sacramento Valley	46	0	0	15	0	11	9	0	17
San Joaquin Valley	21	0	8	44	0	2	20	0	5
Sierra	20	0	2	24	0	36	11	7	0
South Coast	9	0	0	52	0	13	20	0	5

A = Alfisols, C = Andisols, D = Aridisols, E = Entisols, H = Histosols, I = Inceptisols, M = Mollisols, U = Ultisols, V= Vertisols.

Productivity of forest and range soils

Soil productivity, or the ability of soil to grow plants, is related to its chemical and physical properties. These properties include texture, structure, organic matter content, nutrients, and soil acidity (pH). In forest and range communities, vegetation and soils are intimately interconnected. Vegetation provides carbon in the form of leaves, needles, and other litter. Soil organisms transform and transport this carbon and make it useful to plants as part of replenished soil. These organisms chew, mix, burrow, or otherwise change the surface area and chemistry of fresh materials. The productivity of range sites in California is highly varied. Rangeland soils tend to be more productive where they are deeper and there is more rainfall. Less productive soils usually are shallower and climates are more arid. Soils that are more fragile also occur on steep slopes with a harsh environment. The most productive rangeland soils tend to be associated with grassland, hardwood woodland, and wetland/riparian land cover types. Based on vegetative cover type, the site productivity of rangelands, expressed by Animal Units Months of grazing capacity, is estimated (Table 4.15.3).

Table 4.15.3
Total Annual Grazing Capacity on Available Primary Rangeland Cover Types (CAL FIRE, 2003)

Land cover type	Grazing capacity in animal unit months per acre	Area (million acres)
Conifer woodland	0.2	1.6
Grassland	0.7	9.2
Shrub	0.3	11.6
Desert	<0.1	14.3
Hardwood woodland	0.7	4.6
Wetland/riparian	1.8	0.4
Total	0.4	41.7

Forestland productivity can be measured in several ways. The most common is to group areas by general forest types and then rate sites by how long it takes to grow a tree to a specified height (usually 100 years). Soil quality is a key element in why trees grow fast, but other factors such as aspect and rainfall are also reflected in the ability of a site to grow wood. Table 4.15.4 provides a summary of timberland by site class in California.

Table 4.15.4
Area of Timberland by Site Class and Resource Area, 1994 (thousand acres)

	Site class (cubic feet/acre/year)							
Resource Area	20-49	50-84	85-119	120-164 (High)	165-224 (High)	>225 (High)	All classes	Percentage total timberlands in high site classes
North Coast	68	523	1,002	938	486	396	3,413	53
Central Coast	6	15	27	124	63	72	307	84
San Joaquin/Southern	494	707	711	659	63	34	2,688	28
Sacramento	556	995	1,377	1,137	208	25	4,298	32
North Interior	606	2,328	1,916	851	211	33	5,945	18
Total	1,730	4,568	5,053	3,709	1,031	560	16,651	32

4.15.6 Soil Loss

Causes of damage to soil may be natural such as wildfire or intense rain. They may also be related to land use activities such as road building, removal of vegetation, and site disturbance sometimes associated with residential, industrial, commercial development, timber harvesting, and intense grazing. Common factors in soil damage are loss of the litter layer, compaction, and erosion.

The physical presence of an organic layer over soil helps reduce erosion and maintain favorable soil moisture and temperature regimes during hot summers in California (Powers, 2002). Incorporation of organic matter into the soil surface is also an important process affecting soil productivity. Soil organic matter is the primary source for most of the available phosphorous and sulfur, and almost all of the available nitrogen (Imler, 1998).

On annual rangelands, soil surface conditions strongly influence vegetation. Most seeds germinate on the soil surface or at depths to one centimeter (0.4 inches) beneath it. The presence of litter on the surface also seems to impact species composition. Range weeds grow where there is not much surface litter and taller annual grasses such as wild oats tend to grow where litter accumulates (George and Menke, 1996).

The loss of soil cover may substantially increase surface soil erosion (Powers, 2002; George and Menke, 1996). Loss of organic residues may also increase soil temperatures and moisture loss much earlier in the year, thus lessening the period of available soil moisture for forest vegetation.

Soil Erosion

Erosion is the wearing away of the land surface by water, wind, and other geologic agents. Erosion caused by water—the most important agent of erosion from a vegetation management perspective—occurs when the shear stress of water flowing over a slope exceeds the shear resistance of soil particles. The susceptibility of a soil to detachment (i.e., shear resistance) and transport by flowing water varies widely among soils with differing textures; a silt loam soil, for example, may be more than 30 times more erodible than a gravelly clay loam (U.S. Soil Conservation Service, 1993).

Water erosion is classified into three general types: sheet, rill, and gully erosion. Sheet erosion is the removal of soil of a generally uniform depth across a slope and is caused by non-concentrated runoff. Rill erosion refers to the removal of soil in shallow (i.e., less than approximately 6-8 inches deep), usually parallel, channels from a slope and is caused by concentrated runoff. Gully erosion consists of removal of soil from deeper channels and is also caused by concentrated runoff. Although usually less conspicuous than rill and gully erosion, sheet erosion tends to result in greater soil loss over a wide area.

The force of raindrops falling contributes to water erosion. The raindrops dislodge and mobilize soil particles, causing a net downslope soil movement. Raindrops falling on bare soil also cause fine soil particles to plug soil pores, resulting in a crust on the soil surface that may increase runoff rates.

The factors that most influence the inherent wind erodibility of a soil are soil texture, organic matter content, calcium carbonate content, and gravel content (U.S. Soil Conservation Service, 1993). Wind erosion hazard is greatest where such soils occur and high winds are common, vegetation cover has been removed, and the soil has been disturbed.

Erosion Hazard Rating

Each soil survey map unit is rated for water erosion hazard. The erosion hazard rating is qualitative; a typical range is slight/low to severe/extreme. The erosion hazard rating indicates the tendency of erosion to occur when the soil is barren of vegetation or when the soil is disturbed. The primary factors that control water erosion hazard are slope gradient, soil texture, and vegetative cover. Other factors include length of slope, organic matter content, structure (i.e., aggregation characteristics), permeability, and gravel content.

Hydrophobicity and Compaction

Exposing soil to a temperature of 350-400° F., as may occur during a fire, (natural or prescribed burn) may cause the formation of a layer of hydrophobic substances at or just below the soil surface. The hydrophobic layer may cause the soil to resist wetting, thereby reducing soil infiltration rates and increase the potential for rapid runoff and accelerated water erosion (Chamberlin et al., 1991). Heat-induced water repellancy typically persists for a few years (Rieman and Clayton, 1997).

Coarse-textured soils (e.g., sand and loamy sand) with low particle surface area are more prone to the formation of water-repellant layers than fine-textured soils (e.g., clay). The soil's moisture content also affects the depth to which hydrophobic substances penetrate: in dry soils, the substances tend to penetrate to a greater depth than in wet soils (DeBano et al., 1979). In field measurements conducted during a fire, a greater reduction in infiltration capacity was observed in dry soil than in moist soil (DeBano 1991), presumably because the hydrophobic substances were concentrated in a dense layer at the soil surface.

Soil compaction, or the reduction in soil pore space caused by weight applied to the soil surface, usually reduces infiltration and increases runoff and erosion.

Soil Erosion from Fires

The type and intensity of a fire can have widely varying effects on soil properties. For example, a high severity crown fire may sweep quickly across the landscape and cause minimal changes in the heating of the underlying soil. In contrast, a slow moving duff fire may cause extensive heating of soil surface.

Following the passage of surface and crown fires a smoldering fire can still occur in the organic soil horizon. The surface conditions after a fire combined with the presence or absence of rainfall events determine the movement of water and the amount of erosion produced (Table 4.15.5).

Table 4.15.5
Soil Surface Conditions Affect on Infiltration and Runoff (Neary et al., 2005)

Soil surface condition	Infiltration	Runoff	Erosion
Litter charred	High	Low	Low
Litter consumed	Medium	Medium	Medium
Bare soil	Low	High	High
Water repellent layers	Very low	Very high	Severe

Baseline sediment yields in undisturbed forest are relatively low, estimated at 0.01 to 2.47 tons/acre/year for forests in the western states (Neary et al., 2005). Sediment yields associated with fire disturbance are variable and influenced by a complex combination of climate, vegetation, geology, soils, and topography. Table 4.15.6 provides a summary of measured sediment yields associated with wildfires in California and other western states.

Table 4.15.6
Event-Based Sediment Yields from Debris Flows Due to Wildfires (Neary et al., 2005)

Ecoregion-location	Treatment/condition		Sediment yield per event	
	Burn area	Rainfall		
	%	mm	yd^3/mi^2	m^3/km^2
M242 Cascade mixed-conifer-meadow forest province				
Entiat Valley, Washington, 1972	100	335	1,355	400
M262California Coastal Range Woodland-Shrub-Conifer Province				
Los Angeles County, CA, 1914	80	Unknown	60,069	17,730
Los Angeles County, CA, 1928	100	36	45,680	13,483
Los Angeles County, CA, 1933	100	356	67,943	20,054
San Dimas, W. Fork, CA , 1961	100		54,906	16,206
Glendora, Glencoe, CA, 1969	80	1143	203,280	60,000
Glendora, Rainbow, CA, 1969	80	1143	221,026	65,238
Big Sur, Pliefer, CA, 1972	100	31	22,588	6,667
Sierra Madre, CA, 1978	100	38	7,650	2,258
San Bernardino, CA, 1980	NA	Unknown	160,432	47,353
Laguna Canyon, CA, 1993	85	51	73,303	21,636
Hidden Springs, CA, 1978	100	25	84,700	25,000
Sierra Madre, CA, 1978	100	38	1,650	2,258
Topanga, CA, 1994	100	66	783	231
Ventura, Slide Creek, CA 1986	100	122	871	257
M331 Rock Mountain Steppe-Open Woodland-Coniferous Forest				
Glenwood Springs, CO, 1994	97	17	41,537	12,260
Glenwood Springs, CO, 1994	58	17	7,247	2,139
M341 NV-UT Semi-Desert-Coniferous Forest-Alpine Meadow				
Santaquin, UT, 2001	29	12	304,761	89,953
Santaquin, UT, 2001	28	12	31,657	9,344
M313 AZ-NM Mountains Semi-Desert-Woodland-Conifer Province				
Huachuca Mountains, AZ, 1988	80	8	56,468	16,667

CAL FIRE has developed a GIS layer of Post-Fire Erosion potential. This data layer uses a modified version of the Revised Universal Soil Loss Equation (RUSLE) equation to estimate potential soil loss following high severity wildfires. The data has been summarized by Bioregion in Table 4.15.7. The coastal bioregions tend to have a greater proportion of the bioregion area in the highest erosion class.

Soil interrelates with other ecosystem resources in several ways. It supplies air, water, nutrients, and mechanical support for plants. Soil also receives and processes rainfall. By doing so, it partly determines how much rainfall becomes surface runoff, and how much is stored for delivery slowly from upstream slopes to channels where it becomes streamflow, and by how much is stored and used for soil processes (for example, transpiration and leaching). When the infiltration capacity of the soil for rainfall is exceeded, organic and inorganic soil particles are eroded from the soil surface and become a major source of sediment, nutrients, and pollutants in streams that affect water quality.

Soil also is a primary storage for carbon sequestration. Disturbance from fire and management activities can impact the amount of carbon stored in the upper soil profile. For context about 50% of the C is in the soil, 34% is in live vegetation, 8% is in the forest floor, and the rest is in standing dead trees or downed dead wood (Kimble et al., 2000). The values represent the percentage of the Bioregion occupied by a given potential fire erosion class.

Table 4.15.7
Summary of Post-Fire Erosion Potential by Bioregion

Bioregion	No Fuel Rank (Ag/ Barren)	Water or Urban	Low	Moderate	High
Klamath/North Coast	3	2	26	46	23
Modoc	8	6	68	16	2
Sacramento Valley	44	12	38	5	1
Sierra	11	4	46	30	8
Bay Area/Delta	20	25	21	24	10
San Joaquin Valley	55	12	26	6	1
Central Coast	9	4	31	39	17
Mojave	4	4	89	3	0
South Coast	5	30	21	30	13
Colorado Desert	13	8	76	3	0
Total	**13**	**8**	**49**	**21**	**8**

Table 4.15.8
Field Indicators of Existing Landslides and Areas with High Landslide Potential

Indicator	Interpretation
Existing Landslides	
Hummocky topography/slopes	Common feature in old and active progressive slides (slides with many individual components). Slide mass is prone to gullying.
Abrupt change in slope	May indicate either an old landslide area or a change in the erosion characteristics of underlying material. If the feature is a landslide, the portion with low slope angle (the slide mass located below the steep headscarp) is generally weaker and often has higher water content than the steep headscarp and the area upslope from the headscarp.
Scarps and cracks	Definite indication of an active or recently active landslide. Age of scarp can usually be estimated by the amount or maturity of vegetation established upon it. Width of cracks may be monitored to estimate relative rates of movement.
Grabens or “stair step” topography	Indication of progressive failure. Complex or nested series of rotational slides can also cause surface of slope to appear stepped or tiered.
Lobate slope forms	Indication of former earthflow or soil slip area.
Hillside ponds	Local depressions formed as result the formation of “stair step” topography act as infiltration source, which can exacerbate or accelerate landsliding.
Hillside seeps	Can usually be identified by associated presence of denser or phreatophyte vegetation (e.g., cattails, rushes, or alder in vicinity of seep).
Incongruent vegetation	Patches or areas of much younger or very different vegetation (e.g., alder thickets); may indicate recent landslides or unstable ground.
“Jackstrawed” trees	Leaning or canted trees on a slope are indicators of previous episodes of slope movement or soil creep.
High Landslide Potential	
Hillside seeps	Can usually be identified by associated presence of denser or phreatophyte vegetation (e.g., cattails, rushes, or alder in vicinity of seep).
Bedding planes and joints dipping downslope*	Potential planes of weakness for translational slope failure.
Inner gorge	Very steep unstable slope (formed by debris sliding) extending to a stream channel.
Debris slide/amphitheater slope	Steep unstable landform featuring slide scars, incised depressions, and active slide areas.

* Assessment of landslide potential using this indicator should be conducted only by a registered geologist.
Source: Adapted from Gray and Leiser 1982.

Brief description of the soil properties for each soil order:

Soil Order

Soil Order represents the broadest category of soils using the USDA "Soil Taxonomy." The Soil Taxonomy is a basic system of soil classification. There are 12 soil orders, differentiated by the presence or absence of diagnostic horizons: Alfisols, Andisols, Aridisols, Entisols, Gelisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols. Orders are divided into Suborders and the Suborders are farther divided into Great Groups. Ten of the twelve soil orders can be found in California. The following descriptions come from the USDA NRCS web site (http://soils.usda.gov/technical/classification/orders/ and http://soils.usda.gov/technical/soil_orders/).

Alfisols

Alfisols are found in semi-arid to moist areas. These soils result from weathering processes that leach clay minerals and other constituents out of the surface layer and to the subsoil, where they can hold and supply moisture and nutrients to plants. They are formed primarily under forest or mixed vegetative cover and are productive for most crops.

Andisols

The central concept of Andisols is that of soils dominated by short-range-order minerals. They include weakly weathered soils with much volcanic glass as well as more strongly weathered soils. Hence the content of volcanic glass is one of the characteristics used in defining andic soil properties.

Materials with andic soil properties comprise 60 percent or more of the thickness between the mineral soil surface or the top of an organic layer with andic soil properties and a depth of 60 cm or a root limiting layer if shallower.

Aridisols

The central concept of Aridisols is that of soils that are too dry for mesophytic plants to grow. They have either:

(1) An aridic moisture regime and an ochric or anthropic epipedon and one or more of the following with an upper boundry within 100 cm of the soil surface: a calcic, cambic, gypsic, natric, petrocalcic petrogypsic, or a salic horizon or a duripan or an argillic horizon, or

(2)A salic horizon and saturation with water within 100 cm of the soil surface for one month or more in normal years.

An aridic moisture regime is one that in normal years has no water available for plants for more than half the cumulative time that the soil temperature at 50 cm below the surface is >5° C. and has no period as long as 90 consecutive days when there is water available for plants while the soil temperature at 50 cm is continuously >8° C.

Entisols

The central concept of Entisols is that of soils that have little or no evidence of development of pedogenic horizons. Many Entisols have an ochric epipedon and a few have an anthropic epipedon.

Many are sandy or very shallow.

Histosols

The central concept of Histosols is that of soils that are dominantly organic. They are mostly soils that are commonly called bogs, moors, or peats and mucks. A soil is classified as Histosols if it does not have permafrost and is dominated by organic soil materials.

Inceptisols

The central concept of Inceptisols is that of soils of humid and subhumid regions that have altered horizons that have lost bases or iron and aluminum but retain some weatherable minerals. They do not have an illuvial horizon enriched with either silicate clay or with an amorphous mixture of aluminum and organic carbon.

The Inceptisols may have many kinds of diagnostic horizons, but argillic, natric kandic, spodic and oxic horizons are excluded.

Mollisols

The central concept of Mollisols is that of soils that have a dark colored surface horizon and are base rich. Nearly all have a mollic epipedon. Many also have an argillic or natric horizon or a calcic horizon. A few have an albic horizon. Some also have a duripan or a petrocalic horizon.

Spodosols

The central concept of Spodosols is that of soils in which amorphous mixtures of organic matter and aluminum, with or without iron, have accumulated. In undisturbed soils there is normally an overlying eluvial horizon, generally gray to light gray in color, that has the color of more or less uncoated quartz.

Most Spodosols have little silicate clay. The particle-size class is mostly sandy, sandy-skeletal, coarse-loamy, loamy, loamy- skeletal, or coarse-silty.

Ultisols

The central concept of Ultisols is that of soils that have a horizon that contains an appreciable amount of translocated silicate clay (an argillic or kandic horizon) and few bases (base saturation less than 35 percent). Base saturation in most Ultisols decreases with depth.

Vertisols

The central concept of Vertisols is that of soils that have a high content of expending clay and that have at some time of the year deep wide cracks. They shrink when drying and swell when they become wetter.